EFFECT OF ROTATION SPEED AND PULLING RATE ON PHYSICAL PROPERTIES OF TITANIUM-DOPED SAPPHIRE SINGLE CRYSTALS

MOHAMMAD NABIL BIN JAINAL

UNIVERSITI TEKNOLOGI MALAYSIA

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MOHAMMAD NABIL BIN JAINAL

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To my beloved parents,

Jainal Bin Sakiban & Masamah Binti Othman,

To my brother,

Mohammad Ikbal Iskandar,

And to my lovely dear,

Nurul Farhana Binti Jumaat.

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ABSTRACT

Titanium-doped sapphire single crystals with 0.20 weight percentage of dopant were successfully produced by using the Automatic Diameter Control-Crystal Growth System based on the Czochralski technique. Group A crystals were produced at a constant pulling rate of 1.50 mm h^{-1} and a rotational speed (8-24) rpm and Group B crystal were produced at a constant rotational speed of 15 rpm and pulling rate (0.75-1.75) mm h^{-1}. The presence of macroscopic defects such as gas bubbles and inclusions were found in the crystals produced at low rotation speed and at high pulling rate. XRD spectra of the crystals identified synthetic corundum as the main phase of the crystals and Al_2TiO_5 as the second phase. EDAX analysis showed the presence of Al, O and Ti element. Temperature, control power and growth rate were investigated for their correlation on the growth process and crystal diameter profile. When the rotation speed was increased, Group A crystals showed an increase in density from 3.963 g cm^{-3} to 3.999 g cm^{-3}. For group B crystals, the density decreased from 3.988 g cm^{-3} to 3.955 g cm^{-3} with increasing pulling rate. The porosity of the Group A crystals was found to decrease from 0.27% to 0.08% with increasing rotation speed. Group B crystals showed an increase in porosity from 0.09% to 0.44% with increasing pulling rate. From Vickers hardness test, the hardness of Group A crystals increased from 855 HV to 1698 HV with an increase in rotational speed. A decreased in hardness from 1439 HV to 845 HV was observed with increasing pulling rate for Group B crystals. The Young's Modulus of Group A crystals increased from 1542 MPa to 2069 MPa with increasing rotation speed. However, when the pulling rate was increased for the Group B crystals, the Young's Modulus was found to decrease from 2002 MPa to 1311 MPa.

ABSTRAK

Hablur tunggal safir yang didop dengan titanium dengan peratusan berat dopan 0.20 telah berjaya dihasilkan dengan menggunakan Sistem Pertumbuhan Hablur-Kawalan Diameter Automatik berdasarkan kepada teknik Czochralski. Hablur Kumpulan A telah dihasilkan pada kadar tarikan malar 1.50 mm per jam dan kelajuan putaran (8-24) putaran per minit dan hablur Kumpulan B telah dihasilkan dengan kelajuan putaran malar 15 putaran per minit dan kadar tarikan (0.75-1.75) mm per jam. Kehadiran kecacatan makroskopik seperti gelembung gas dan bendasing telah ditemui dalam hablur yang dihasilkan pada kelajuan putaran yang rendah dan kadar tarikan yang tinggi. Spektrum XRD daripada hablur telah mengenalpasti korundum sintetik sebagai fasa utama hablur dan $Al_2Ti_2O_5$ sebagai fasa kedua. Analisis EDAX menunjukkan kehadiran elemen Al, O dan Ti. Suhu, kuasa kawalan dan kadar pertumbuhan telah dikaji untuk hubungkaitnya pada proses pertumbuhan dan profil diameter hablur. Apabila kelajuan putaran bertambah, hablur Kumpulan A menunjukkan peningkatan dalam ketumpatan dari 3.963 g cm^{-3} ke 3.999 g cm^{-3}. Bagi hablur Kumpulan B, ketumpatannya susut dari 3.988 g cm^{-3} to 3.955 g cm^{-3} dengan meningkatnya kadar tarikan. Keporosan hablur kumpulan A didapati susut dari 0.27% ke 0.08% dengan meningkatnya kelajuan putaran. Hablur Kumpulan B menunjukkan pertambahan keporosan dari 0.09% ke 0.44% dengan peningkatan kadar tarikan. Daripada ujian kekerasan Vickers, kekerasan hablur Kumpulan A bertambah dari 855 HV ke 1698 HV dengan peningkatan kelajuan putaran. Penyusutan kekerasan dari 1439 HV ke 845 HV telah diamati dengan peningkatan kadar tarikan bagi hablur Kumpulan B. Modulus Young bagi hablur Kumpulan A meningkat dari 1542 MPa ke 2069 MPa dengan peningkatan kelajuan putaran. Bagaimanapun, apabila kadar tarikan ditingkatkan bagi hablur Kumpulan B, Modulus Young didapati susut dari 2002 MPa ke 1311 MPa.